Part I: Electricity

Chapter 23

Electric Fields

Dr. Saif M. H. Qaid

LECTURE OUTLINE

- **23.1** Properties of Electric Charges
- **23.3** Coulomb's Law
- **23.4** Analysis Model: Particle in a Field (Electric)
- **23.6** Electric Field Lines

Electric Field – Introduction

- The electric force is a field force
- Field forces can act through space
  - The effect is produced even with no physical contact between objects
- Faraday developed the concept of a field in terms of electric fields

المجال الكهربي Electric field

أي جسم مشحون بشحنة q يصاحبه مجال كهربي E و يحيط به.

يكتشف بوضع شحنة اختبار $+q_o$، فإذا تأثرت هذه الشحنة بقوة

كهربية (تجاذب أوتنافر) فهذا يعني وجود مجال كهربي.

Electric Field – Definition

- An **electric field** is said to exist in the region of space around a charged object
  - This charged object is the **source charge**
- When another charged object, the **test charge**, enters this electric field, an electric force acts on it

Electric Field – Definition, cont

- The electric field is defined as the electric force on the test charge per unit charge
- The electric field vector, $\vec{\mathbf{E}}$, at a point in space is defined as the electric force $\vec{\mathbf{F}}$ acting on a positive test charge, q_o placed at that point divided by the test charge:

$$\vec{\mathbf{E}} \equiv \frac{\vec{\mathbf{F}}}{q_o}$$

Electric Field

المجال الكهربي يمثل القوة المؤثرة على وحدة الشحنات الموجودة في هذا المجال؛ أي أن:

$$\vec{\mathbf{F}}_e = k_e \frac{q q_0}{r^2} \hat{\mathbf{r}}$$

وباستخدام قانون كولوم نحصل على الصيغة التالية للمجال الكهربى.

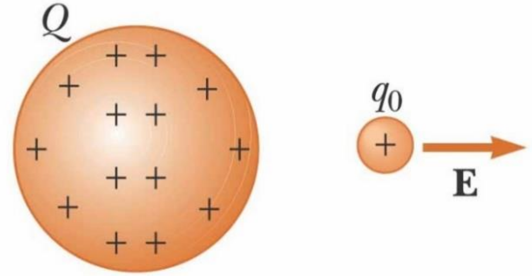
$$E = \frac{F}{q_o} \qquad E = K_e \frac{q}{r^2} \qquad \vec{\mathbf{E}} = k_e \frac{q}{r^2} \hat{\mathbf{r}}$$

Electric Field, Notes

- $\vec{E}$ is the field produced by some charge or charge distribution, separate from the test charge
- The existence of an electric field is a property of the source charge
  - The presence of the test charge is not necessary for the field to exist
- The test charge serves as a detector of the field

Electric Field, Notes

- The direction of $\vec{\mathbf{E}}$ is that of the force on a positive test charge
- The SI units of $\vec{\mathbf{E}}$ are N/C
- We can also say that an electric field exists at a point if a test charge at that point experiences an electric force



Relationship Between F and E

- $\vec{\mathbf{F}}_e = q\vec{\mathbf{E}}$
  - This is valid for a point charge only
  - One of zero size
  - For larger objects, the field may vary over the size of the object
- If q is positive, the force and the field are in the same direction
- If q is negative, the force and the field are in opposite directions

Electric Field, Vector Form

- Remember Coulomb's law, between the source and test charges, can be expressed as

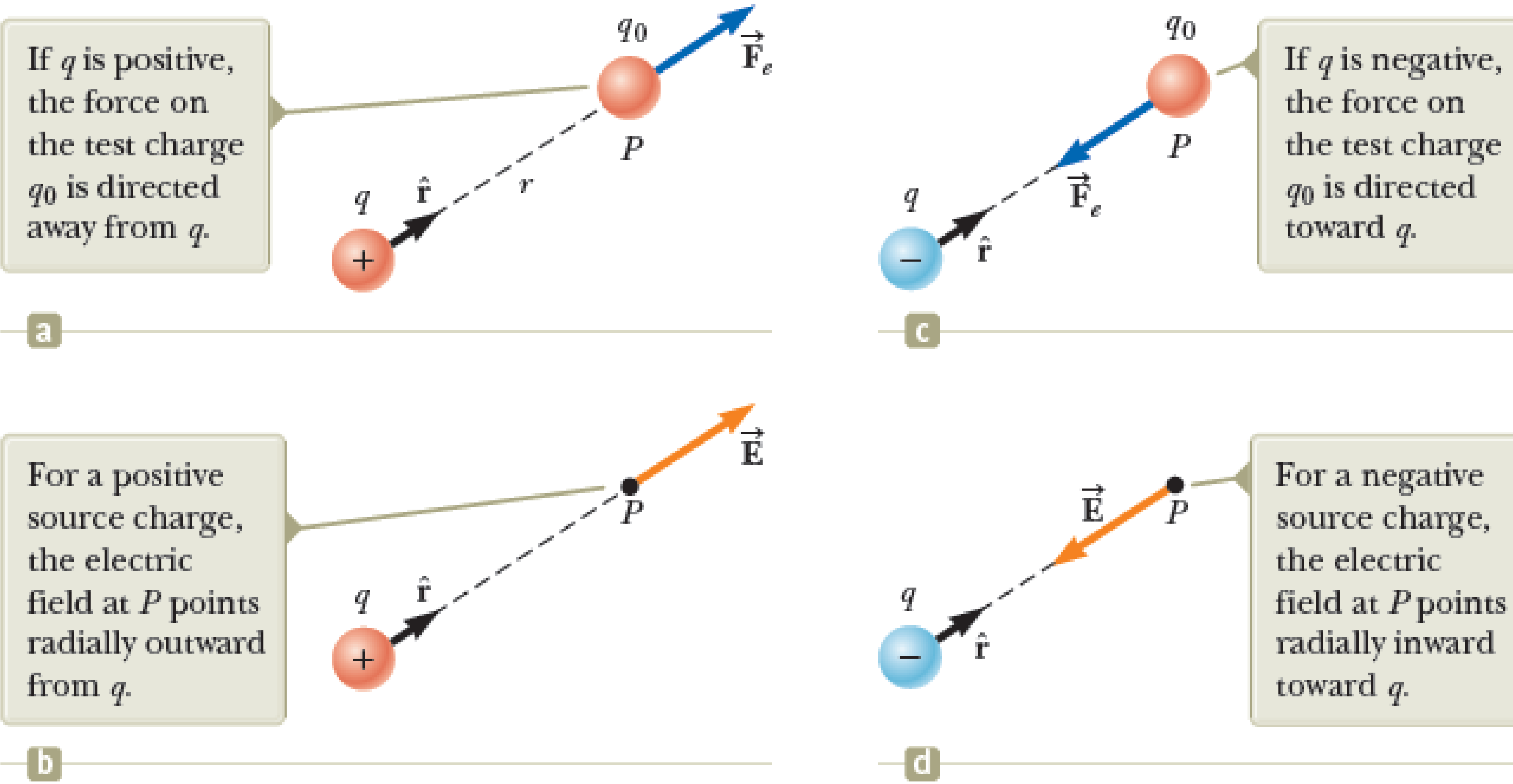
$$\vec{\mathbf{F}}_e = k_e \frac{qq_o}{r^2}\hat{\mathbf{r}}$$

- Then, the electric field will be

$$\vec{\mathbf{E}} = \frac{\vec{\mathbf{F}}_e}{q_o} = k_e \frac{q}{r^2}\hat{\mathbf{r}}$$

More About Electric Field Direction

- يكون اتجاه المجال الكهربي في نفس اتجاه القوة المؤثرة على شحنة الاختبار الموجبة Kوفي عكس إتجاه القوة إذا كانت شحنة الاختبار سالبة.



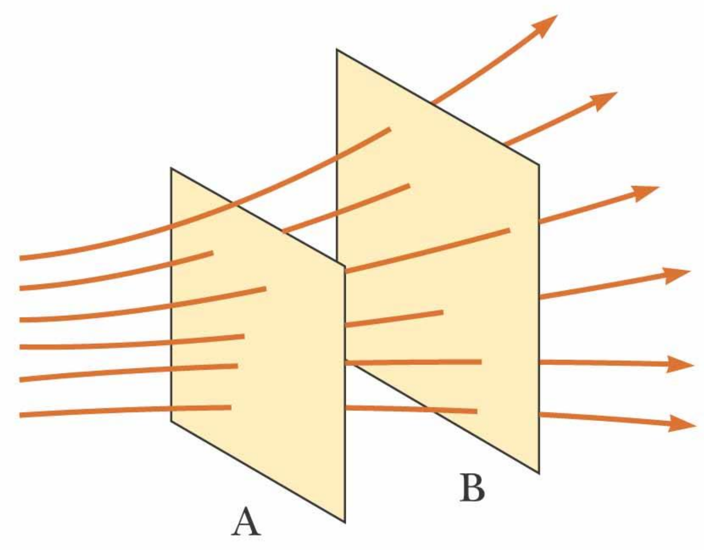
- خطوط القوى الكهربية هي خطوط وهمية تستخدم لوصف المجال الكهربي مقدارا واتجاها.

23.6 Electric Field Lines

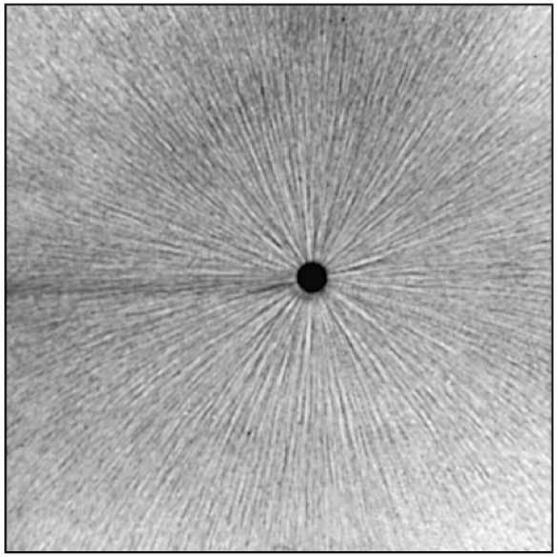
- Field lines give us a means of representing the electric field pictorially
- The electric field vector $\vec{\mathbf{E}}$ is tangent to the electric field line at each point
  - The line has a direction that is the same as that of the electric field vector
- The number of lines per unit area through a surface perpendicular to the lines is proportional to the magnitude of the electric field in that region

Electric Field Lines, General

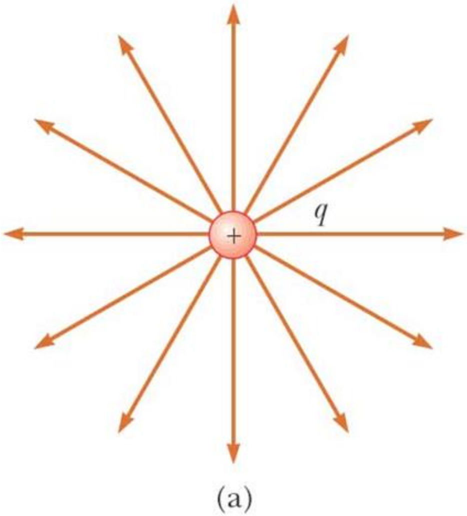
- The density of lines through surface A is greater than through surface B
- The magnitude of the electric field is greater on surface A than B
- The lines at different locations point in different directions
  - This indicates the field is nonuniform



Electric Field Lines, Positive Point Charge



Lines of Force
Point Charge

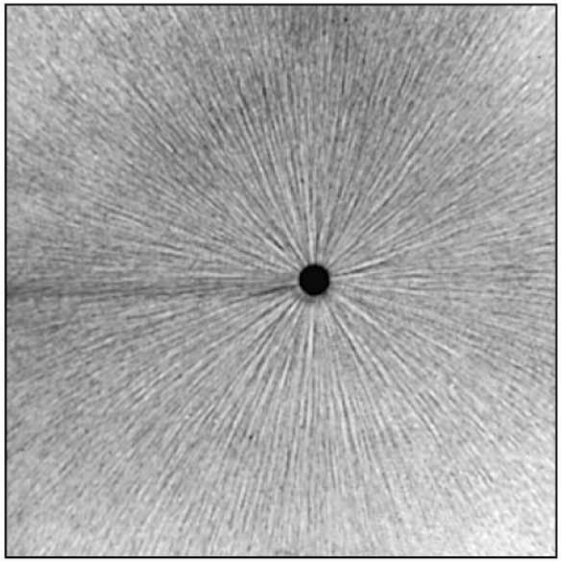


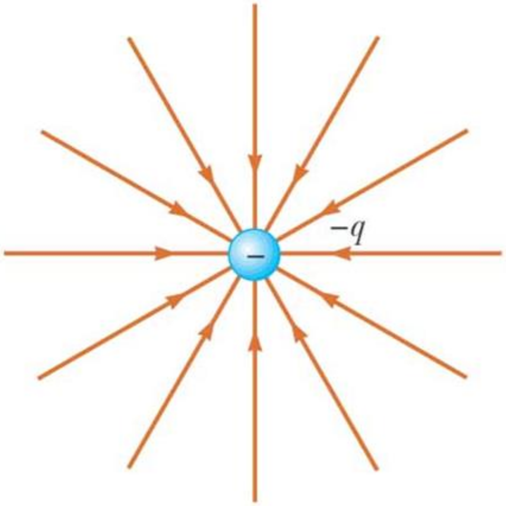
(a)

- The field lines radiate outward in all directions
  - In three dimensions, the distribution is spherical
- The lines are directed away from the source charge
  - A positive test charge would be repelled away from the positive source charge

تتجه خطوط القوى الكهربية للخارج في حالة الشحنة الموجبة

Electric Field Lines, Negative Point Charge



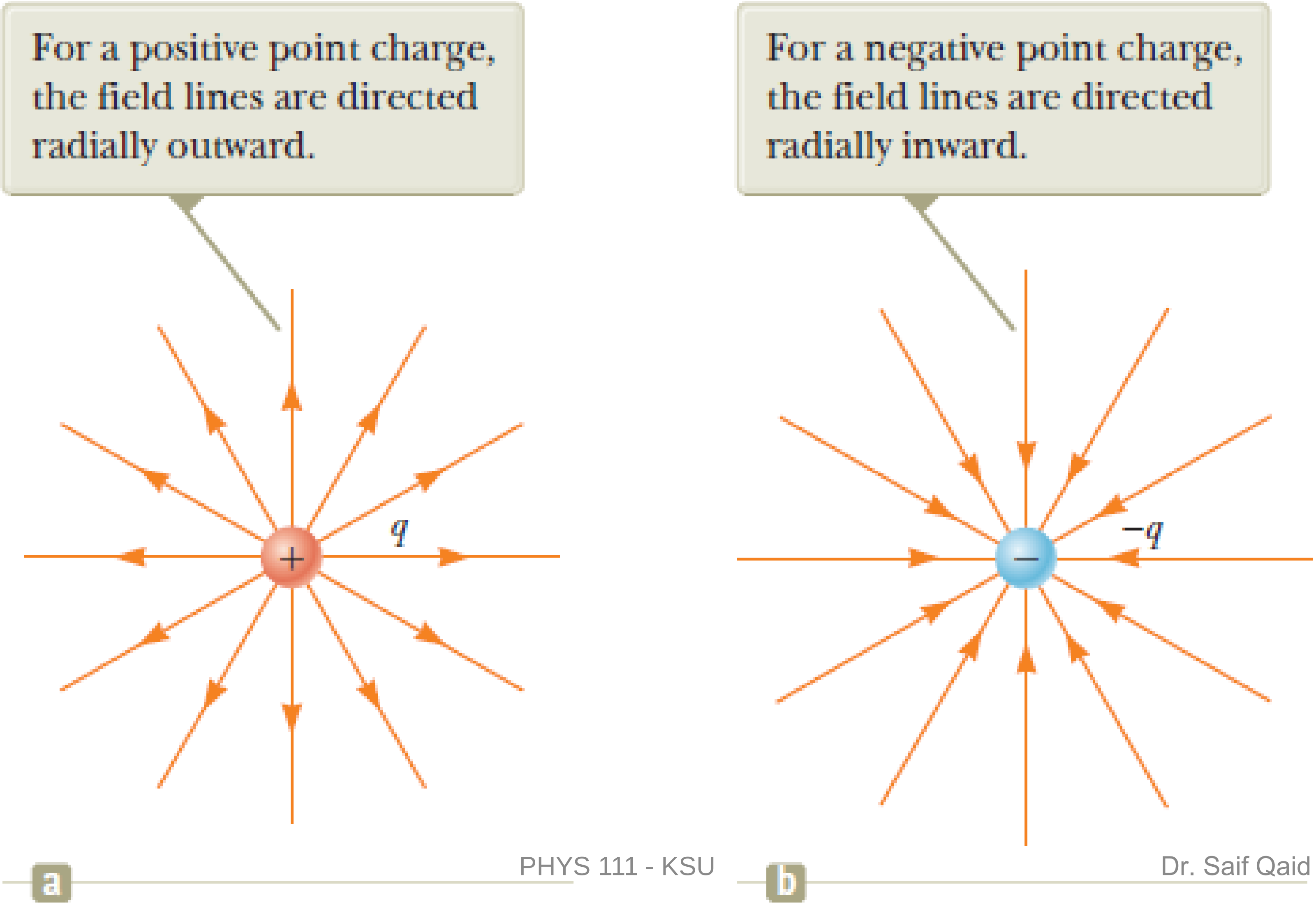


(b)

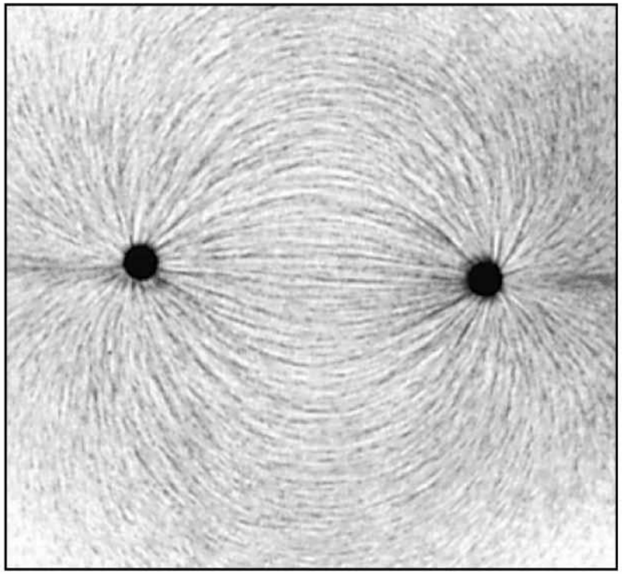
- The field lines radiate inward in all directions
- The lines are directed toward the source charge
  - A positive test charge would be attracted toward the negative source charge

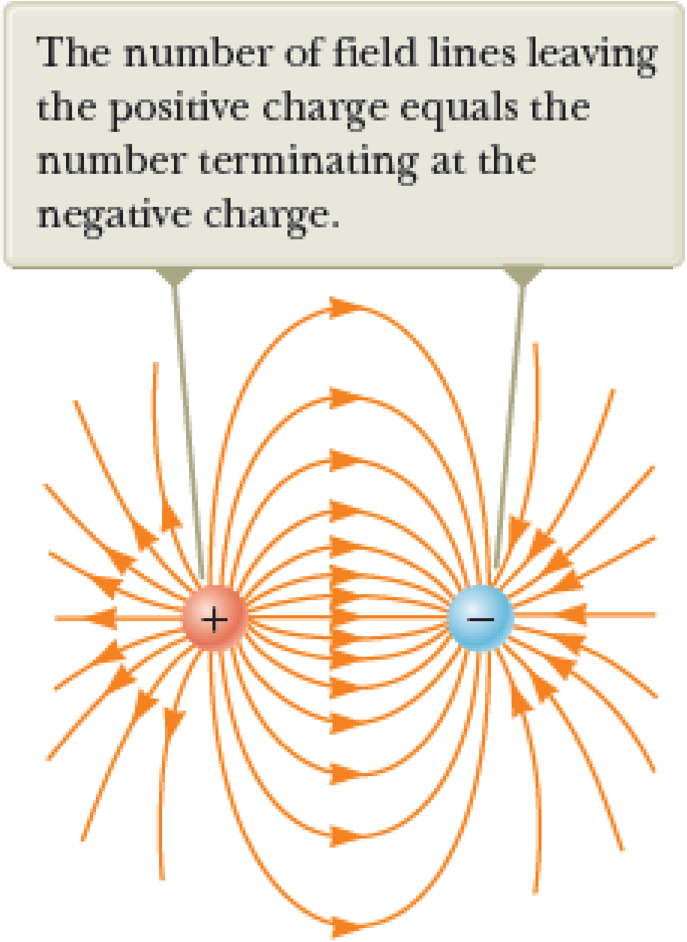
وتتجه للداخل في حالة الشحنة السالبة

Electric Field Lines



Electric Field Lines – Dipole

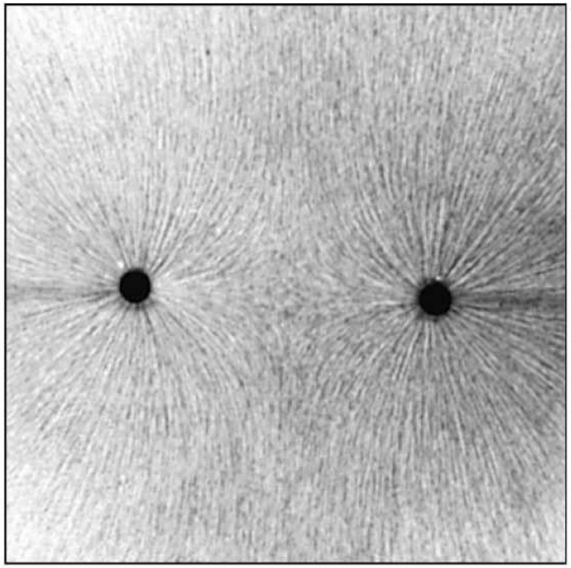


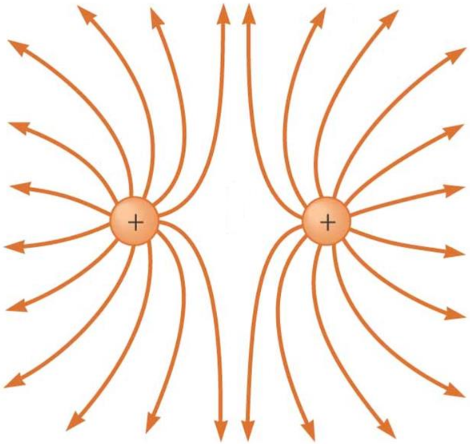


- The charges are equal and opposite
- The number of field lines leaving the positive charge equals the number of lines terminating on the negative charge

خطوط القوى في حالة شحنتين متساويتين في القيمة ومختلفتين في النوع

Electric Field Lines – Like Charges



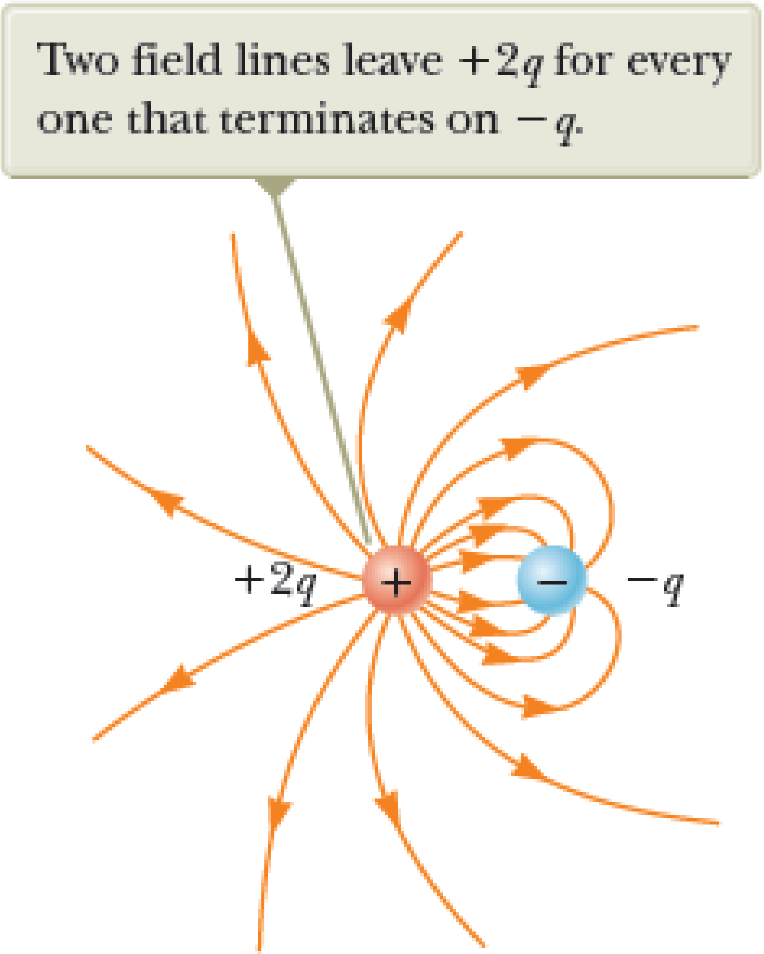


- The charges are equal and positive
- The same number of lines leave each charge since they are equal in magnitude
- At a great distance, the field is approximately equal to that of a single charge of $2q$

خطوط القوى في حالة شحنتين متساويتين في القيمة والنوع

Electric Field Lines, Unequal Charges

- The positive charge is twice the magnitude of the negative charge
- Two lines leave the positive charge for each line that terminates on the negative charge
- At a great distance, the field would be approximately the same as that due to a single charge of $+q$
- Use the active figure to vary the charges and positions and observe the resulting electric field



خطوط القوى في حالة شحنتين مختلفتين في القيمة والنوع

Electric Field Lines – Rules for Drawing

The rules for drawing electric field lines are as follows:

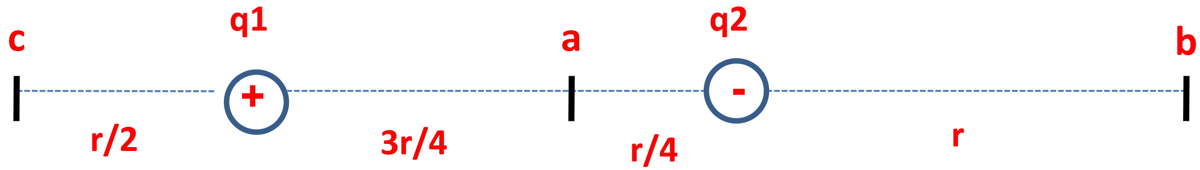
- The lines must begin on a positive charge and terminate on a negative charge
  – In the case of an excess of one type of charge, some lines will begin or end infinitely far away
- The number of lines drawn leaving a positive charge or approaching a negative charge is proportional to the magnitude of the charge
- No two field lines can cross
- Remember field lines are **not** material objects, they are a pictorial representation used to qualitatively describe the electric field

Electric field, Example

Tow point charges lie along the *x* axis as shown in Figure. Find the electric filed at points a, b, c.

في المثال 1-1 حسبنا القوة المؤثرة على شحنة q عند النقاط c, b, a

احسب الآن المجال الكهربي وبين اتجاهه عند النقاط السابقة .



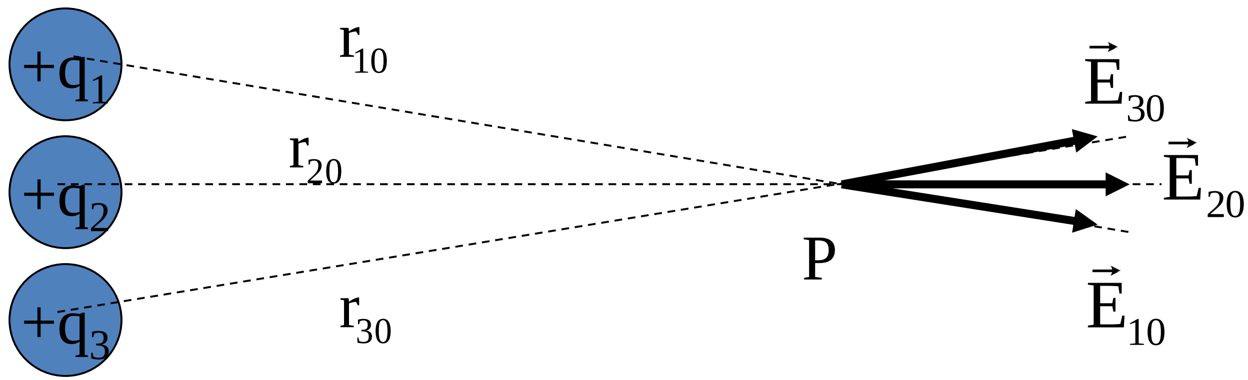
Superposition with Electric Fields

- At any point *P*, the total electric field due to a group of source charges equals the vector sum of the electric fields of all the charges

$$\vec{\mathbf{E}} = k_e \sum_i \frac{q_i}{r_i^2} \hat{\mathbf{r}}_i$$

Superposition of Fields

$$\vec{E}_P = \vec{E}_{1P} + \vec{E}_{2P} + \vec{E}_{3P} + \ldots.$$

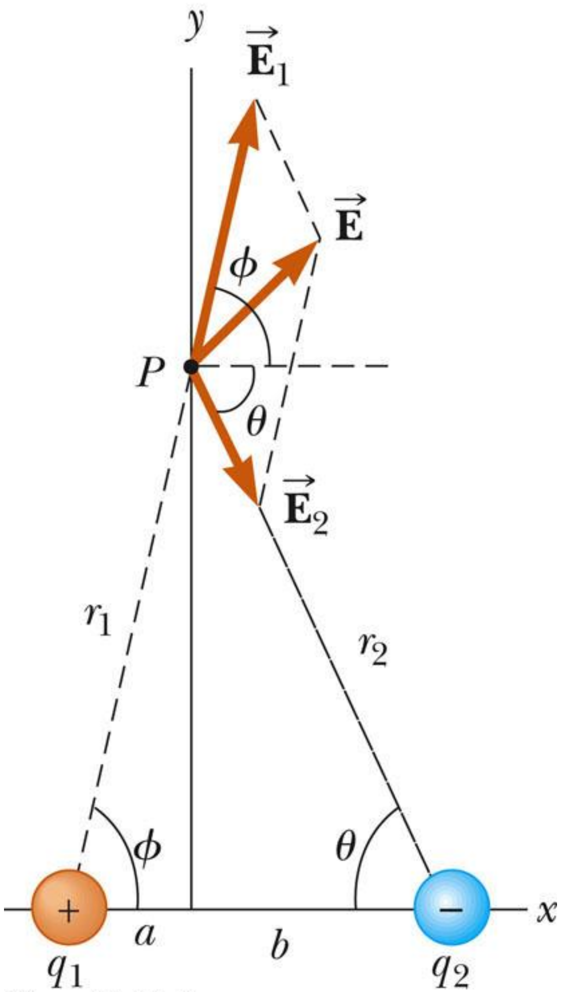


$$\vec{E}_P = \frac{kq_1}{r_{10}^2}\hat{r}_{10} + \frac{kq_2}{r_{20}^2}\hat{r}_{20} + \frac{kq_3}{r_{30}^2}\hat{r}_{30} + \ldots.$$

$$\vec{E}_P = k\left(\frac{q_1}{r_{10}^2}\hat{r}_{10} + \frac{q_2}{r_{20}^2}\hat{r}_{20} + \frac{q_3}{r_{30}^2}\hat{r}_{30} + \ldots.\right) = k\sum_{i=1}^{N}\frac{q_i}{r_{i0}^2}\hat{r}_{i0}$$

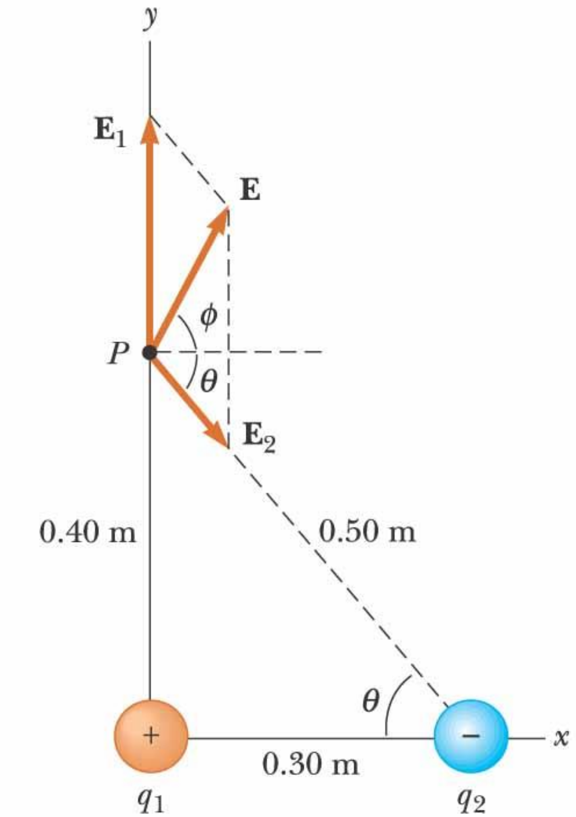
Superposition Example

- Find the electric field due to q_1, $\vec{\mathbf{E}}_1$
- Find the electric field due to q_2, $\vec{\mathbf{E}}_2$
- $\vec{\mathbf{E}} = \vec{\mathbf{E}}_1 + \vec{\mathbf{E}}_2$
  - Remember, the fields add as vectors
  - The direction of the individual fields is the direction of the force on a positive test charge

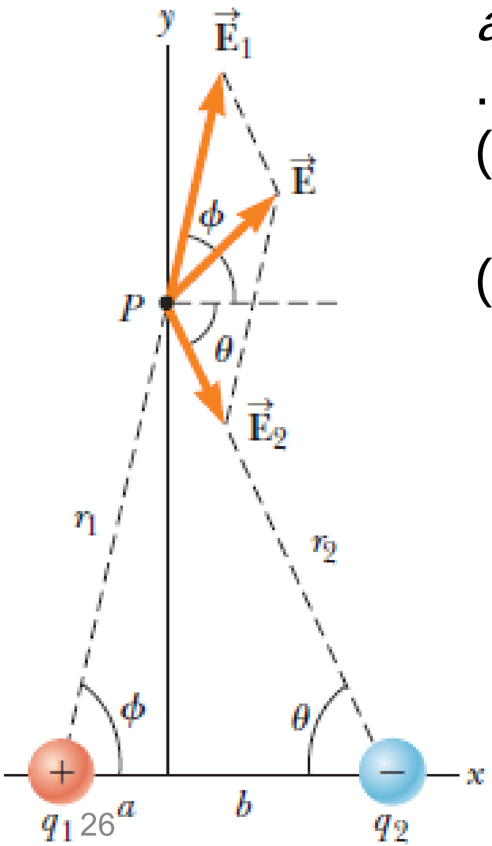


Superposition Example

- Find the electric field due to q_1, $\mathbf{E}_1$
- Find the electric field due to q_2, $\mathbf{E}_2$
- $\mathbf{E} = \mathbf{E}_1 + \mathbf{E}_2$
  - Remember, the fields add as vectors
  - The direction of the individual fields is the direction of the force on a positive test charge



Superposition Example



Charges q_1 and q_2 are located on the *x* axis, at distances *a* and *b*, respectively, from the origin as shown in Figure .

(A) Find the components of the net electric field at the point *P*, which is at position (0, *y*).

(B) Evaluate the electric field at point *P* in the special case that $|q_1| = |q_2|$ and $a = b$.

Summary الخلاصة

$$E = \frac{F}{q_o}$$

The electric field E at some point in space is defined as the electric force F_e that acts on a small positive test charge placed at that point divided by the magnitude q_0 of the test charge:

- المجال الكهربي

- If q is positive, the force and the field are in the same direction
- If q is negative, the force and the field are in opposite directions

Thank You

ACKNOWLEDGEMENTS